Gas holdup in laboratory scale bubble column: CFD simulations vs. measurements

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This contribution deals with CFD Euler-Euler simulation of laboratory scale rectangular bubble column. Horizontal profiles of gas holdup obtained from simulations are compared with experimentally measured profiles using optical fiber probe.

Goal

The goal of the presented contribution was two-fold. Goal 1 was to examine effect of interphase forces and turbulent models on simulation results and effect of front-rear flow field symmetry assumption. Goal 2 was to compare simulated horizontal profiles of gas holdup with profiles measured with optical fiber probe.

Experiments

Experimental column width was 20 cm, measurements were done for column thickness 4 and 10 cm. Ungassed liquid height was 25 and 50 cm. Water and air were used as liquid and gas phase. Gas distributor consisted of one line of 33 orifices (0.5 mm orifice diameter, 5 mm distance between two neighbouring orifices). Experiments were done for air flow rates 800, 1200 and 1800 l/h. Gas holdup profiles were measured at height 11, 21, 31 and 41 cm above the gas distributor. There were 19 measuring points in horizontal profile with distance 1 cm. Local gas holdup at each point was measured for 2 minutes - the obtained values are 2 min time averages.

Simulations

Euler-Euler model was used for the simulation of gas-liquid flow in the bubble column. Model equations were solved using commercial code Fluent 6.3. In Euler-Euler model all involved phases (gas, liquid, (solid)) are treated as interpenetrating continua (see e.g. [1], [2], [3]). There is continuity and momentum equation for each particular phase. These equation sets for each phase are coupled together through pressure, phase volume fractions (which sum to unity) and interphase force terms like drag, lift, added mass force. Closure relations for the interphase forces are needed to solve the equations. Also turbulence has to be modelled.

We did 3-dimensional transient simulations of the flow field in the bubble column. One set of simulations was done assuming front-rear symmetry of the flow field, another set was done without this assumption (full 3D). Three version of k-ε turbulence model were tested (standard, RNG and realizable). Also simulations with different combinations of enabled interphase forces (drag, drag + lift, drag + added mass, drag + lift + added mass force) were run to see how they influence the output. Influence of the lift coefficient value (from -0.3 to 0.5) on results was examined.

Time averaged horizontal profiles of gas holdup were compared with experimental data. Profiles obtained from simulations were averaged over 60s time interval. Time averaging was started after 30s to let the flow field reach a pseudosteady state.

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Results

Goal 1. The difference in gas holdup profiles calculated with and without the front-rear symmetry assumption was often larger than 20 %, thus the symmetry assumption is not recommended for column simulation even when the column thickness is only 4cm. Each of the simulations using different version of k-ε turbulence model predicted qualitatively different results – two different steady flow fields in the case of standard and realizable model, unsteady flow field in the case of RNG model. RNG k-ε model gave best agreement with experiments. Lift force (lift coefficient values) significantly influenced simulation output, influence of the added mass force was smaller.

Goal 2. Qualitative agreement between simulations and experiments was reached, when drag, lift and added mass force were accounted for, see Fig. 1.

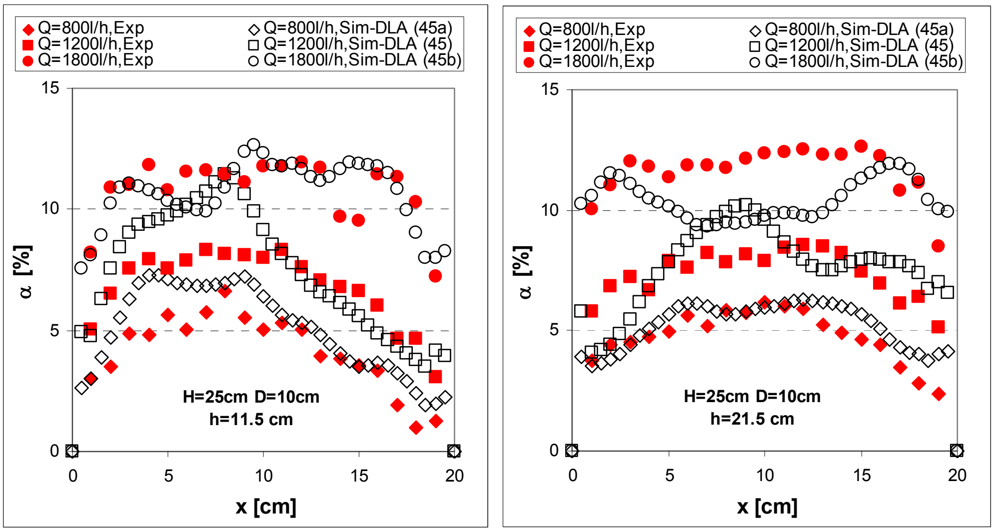

Fig. 1: Simulated (white marks) and experimental (red marks) holdup profiles at two heights h above gas distributor for air flow rates 800, 1200 and 1800l/h. Ungassed liquid level 25 cm. column thickness 10 cm.

Acknowledgements

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References

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